NASA Innovative Advanced Concepts

High-Temperature Superconductors as Electromagnetic Deployment and Support Structures

Completed Technology Project (2012 - 2014)

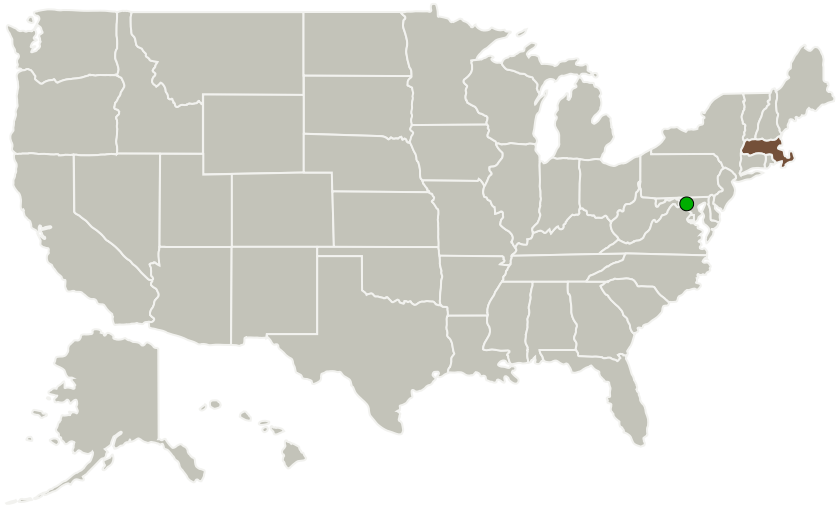
Project Introduction

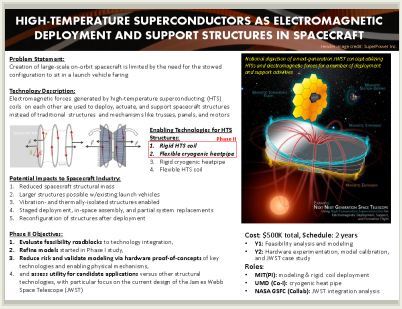
This technique uses the magnetic fields from current passing through coils of high-temperature superconductors (HTSs) to support spacecraft structures and deploy them to operational configurations from their positions as stowed inside a launch vehicle fairing. The chief limiting factor in spacecraft design today is the prohibitively large launch cost per unit mass. Therefore, the reduction of spacecraft mass has been a primary design driver for the last several decades. The traditional approach to the reduction of spacecraft mass is the optimization of actuators and structures to use the minimum material required for support, deployment, and interconnection. Isogrid panels, aluminum or composites, and gas-filled inflatable beams all reduce the mass of material necessary to build a truss or otherwise apply surface forces to a spacecraft structure. We instead look at using electromagnetic body forces generated by HTSs to reduce the need for material, load bearing support, and standoffs on spacecraft by maintaining spacing, stability, and position of elements with respect to one another.

Anticipated Benefits

HTS structures present an opportunity for significant mass savings over traditional options, especially in larger systems that require massive structural components.

Primary U.S. Work Locations and Key Partners





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Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland
University of Maryland-College Park(UMCP)	Supporting Organization	Academia	College Park, Maryland

Primary U.S. Work Locations
Massachusetts

Project Transitions

September 2012: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

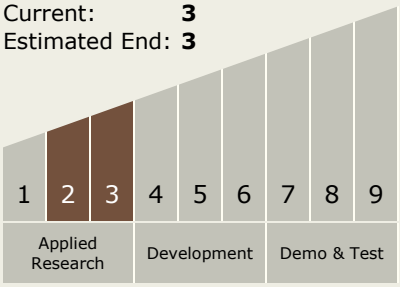
Eric A Eberly

Principal Investigator:

David M Miller

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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August 2014: Closed out

Closeout Summary: This report concludes the work being conducted under the MAGESTIC NIAC Phase II, save for where it continues as graduate student dissertation work. Initially, we divided the barriers to feasibility that we wished to address into three categories: Power/Thermal, Dynamics/Control, and Integration (before we later recategorized the focus groups as Power Management and Control, Thermal, and Electromagnets and Deployment). As expected, the areas that demanded our focus were not necessarily the ones we initially predicted. In the following sections, the barriers to feasibility that were mentioned in the proposal are listed, with the one(s) that were focused on bolded and discussed. Power/Thermal: -Cost: Complex power and thermal control, generation and management -Cost: Thermal vacuum chamber testing expenses -Performance: Power for HTS operations needing to be taken from other subsystems -Key technology: Low-power rigid and flexible cryogenic heatpipes -Performance: Lower power cryocoolers The primary focus of UMD during this study was the development of a flexible and deployable thermal enclosure and heat removal system, and despite some changes from the original bellows-like concept, a very innovative system was designed, though the limits of the laboratory environment have come to bear upon it. Cryocoolers still remain the most massive and power-hungry elements of the electromagnetic system.Dynamics/Control: -Performance: Coil dynamics -Performance: Stability of configuration -Performance: Position accuracy and knowledge -Performance: Disturbances (Cryocooler vibration, solar pressure) Coil dynamics and stability became a major focus in the second half of the study, when it was realized that a lack of stability conditions for electromagnetically supported and tethered structures could undermine the rest of the work if there proved to be instability that was uncorrectable by changes in boom design parameters or changes in connective hardware like tethers and attachment points. It is work that is continuing beyond the auspices of this study and will hopefully provide added support for the conclusions and ideas set forth in this and our Phase I report. Integration: -Cost: Cost may be uncompetitive with other structural options -Performance: Performance may be uncompetitive in multi-subsystem tradespace -Performance: Potential EMI, negatively affecting other subsystems on board or vice versa -Development Time: Technology roadmap may be too linear to allow missions to use less complex HTS structures as flight hardware prior to completion

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - TX12.2 Structures
    - TX12.2.5 Innovative, Multifunctional Concepts

Target Destination

Foundational Knowledge

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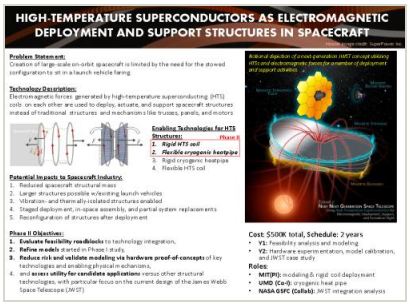
Images



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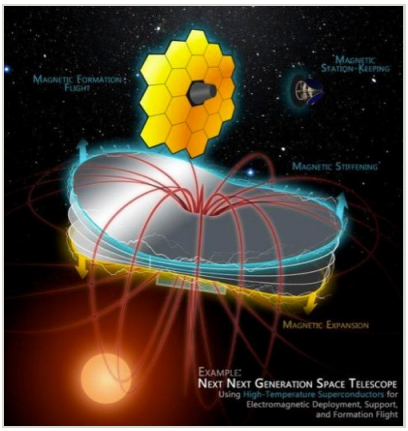

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High-Temperature Superconductors as Electromagnetic Deployment and Support Structures *(https://techport.nasa.gov/image/102116)*

Links

Study Page
(https://www.nasa.gov/directorates/spacetech/niac/2012_Phase_II_high_temp_superconductors/)